Section 13
On-Orbit Maintenance Overview

13.1 Introduction

Keeping the Space Station working in a nominal mode requires more maintenance activity than we have seen in past programs. Both potential crewmembers and flight controllers, will have some experience with On-Orbit Maintenance (OOM) during the Space Station Program. Crewmembers may have to troubleshoot, service, or replace an Orbital Replacement Unit (ORU). Flight controllers may have to perform procedures to determine the status of a particular ORU or to isolate it from the rest of a system so a crewmember can remove and replace it. This section presents the nomenclature, philosophy, and strategy of OOM.

13.2 Objectives

Upon completing this section, you should be able to

- Describe the International Space Station (ISS) operational maintenance philosophy
- Describe the maintenance roles and responsibilities of the International Partners (IPs)
- Summarize the different methods, types, and levels of OOM
- Summarize the typical tools and procedures used in OOM

13.3 Maintenance Philosophy/Definitions

Several unique factors of ISS, relative to previous U.S. space vehicles, have influenced the ISS philosophy of maintenance. The first unique factor is that the ISS never returns to the ground. Presently, mechanical malfunctions on the Space Shuttle are handled by applying temporary repairs which allow the shuttle to continue to function safely both on orbit and during re-entry. Once on the ground, the vehicle is thoroughly inspected and any defective systems or Line Replaceable Units (LRUs) are repaired or replaced. The result is a vehicle which is “like new” and ready for another launch. All ground repairs are considered to be permanent. Conversely, since the ISS never returns to the ground, all repairs must be made on orbit. Since the ISS is designed to operate for many years, all repairs must be designed to be permanent. (In space, temporary fixes are risky and may take more of the crew’s time than permanent repairs.) Here, the crew functions as both the operators and the maintainers of the ISS systems.

Another unique aspect of the ISS is that the entire vehicle is assembled in orbit. The zero-g environment of space causes special problems for crewmembers. Tools and loose ORUs have to be tethered and small parts restrained so that they do not float away. Crewmembers have to determine the best method of anchoring themselves while they attempt to remove and replace defective ORUs and parts. In the Intravehicular Activity (IVA) environment, particles of debris caused by drilling and filing operations have to be collected and disposed of so they do not contaminate the crew's environment.

Finally, the lack of comprehensive end-to-end testing of the ISS components carries a great deal of potential for subsequent problems. Ideally, all of the ISS modules and trusses are assembled on the ground; the mechanical and electrical interfaces between the various modules and trusses are tested; and any problems are repaired. The vehicle is then disassembled and the components carried into orbit by various launch vehicles. In the ISS program, this is not the case. Many times the testing of the interface between two mating modules is impossible, because while one module is being carried into space, the module with which it interfaces is still being assembled on the ground.

The Hubble Space Telescope program's reduced budget resulted in the fact that a final end-to-end test of the telescope's mirror was never conducted. A spherical aberration in the mirror was not discovered until the telescope was in orbit. Repairs to the telescope while in orbit were costly and required many difficult Extravehicular Activities (EVAs) to correct the problem.

The key to success for the ISS is timely and effective maintenance. The ISS program will be judged by the quality and quantity of science data produced: it is essential the science-producing payloads are kept operating as long as possible. To function nominally, payloads require ISS services such as electrical power, cooling, pressurized gases and Command and Data Handling (C&DH). Again, to keep all of these services operating in a nominal manner, timely maintenance is essential.

13.3.1 On-Orbit Maintenance Philosophy

The ISS OOM philosophy is to use available resources to maintain, repair and replace failed ISS hardware components and return the affected systems to their original configuration and efficiency.

Contrast this with the present shuttle in-flight maintenance philosophy:

- The use of temporary repairs and organizational maintenance (removal and replacement or cannibalization of selective LRUs) to ensure mission success, or to increase levels of safety
- Permanent repairs will be made after the vehicle lands (during ground processing)

NASA and the Russian Space Agency (RSA) have slightly different approaches to maintenance conducted on space stations. NASA's baseline approach for the ISS is to remove and replace defective ORUs in their entirety. In limited cases, where time considerations and the lack of a spare ORU do not permit replacement, repairs are made to a part of an ORU. This approach is based on the idea that replacing ORUs requires less crew training and reduces the amount of crew time required to make repairs, thus increasing the amount of time to perform science.

The RSA approach for MIR seems to be to repair ORUs in-situ (in place) on orbit. In some cases, where the particular ORU is a critical one, the temporarily repaired ORU is replaced by a spare ORU when it becomes available via a Progress resupply flight. In the past, RSA has had limited down-mass capabilities, requiring all ORUs to be maintained on orbit. Generally, ground servicing has not been an option.

The ISS requires cooperation from the various IPs in all areas, including maintenance. IPs are responsible for the following activities for their respective components of Station hardware: planning; training; and execution of maintenance procedures.

In addition, each IP is responsible for providing their own tool kits (metric). Tool sharing between IPs is expected. In some cases, one IP's spare parts may be delivered to orbit by another IP's launch vehicle. In the event of the loss of a component which is critical to crew safety, vehicle integrity, or mission success, and if the IPs agree to it, parts may be borrowed or "cannibalized" from one IP module and used in another.

13.3.2 Methods of On-Orbit Maintenance

There are three distinct modes of performing maintenance on the ISS.

- IVA - Performed inside the vehicle
- EVA - Performed outside the vehicle, using special EVA tools, restraints and aids (CETA cart)
- EVR (Extravehicular Robotics) - Using the Space Station Remote Manipulator System (SSRMS) alone or in conjunction with EVA to perform external maintenance. Using the SSRMS alone to perform external maintenance is the preferred method of performing EVR, since this minimizes the crewmembers' exposure to the hazards of the space environment. When performed in conjunction with EVA, the SSRMS may be used to either move the work to the crewmember, or the crewmember to the worksite

For an example of a maintenance activity involving all three modes of maintenance, consider a failed external video camera luminaire unit.

- EVA - The crewmember goes EVA
- EVR - The SSRMS is used to position the EVA crewmember in the vicinity of luminaire assembly
- EVA - The crewmember removes the luminaire assembly and takes it inside
- IVA - The bulb is removed from the luminaire assembly and replaced (at Maintenance Work Area (MWA))
- This process is reversed to put the luminaire assembly back in its original location

Maintenance operations play an important role in overall ISS operations

(Interesting data concerning OOM)

Estimates for ISS crew time for maintenance are as follows: (Based on data from Logistics and Maintenance IPT).

- 421 EVA   Total mean maintenance crew hours per year
- 777 EVR   Total mean maintenance crew hours per year
- 2536 IVA Total mean maintenance crew hours per year

Presently, RSA maintenance of Mir requires approximately 75 percent of the crew workday (Above figures represent long-term averages and include preventive maintenance time.)

13.3.3 Types of On-Orbit Maintenance

The following categories of maintenance are based on either the urgency of the maintenance, the time frame, or the place the maintenance will be carried out.

- Preventive - Keeps item(s) in a specified condition by performing systematic inspection, detection, cleaning, repair and/or replacement of parts at preplanned, specified intervals
- Corrective - Restores an item to its original condition.
- In-Situ - Performs repairs at the hardware site.
- Contingency - Performs maintenance to restore a function which is vital to crew safety or vehicle integrity. May require immediate action.

Note that based on the definitions above, there may be overlaps between different types of maintenance. For example, if corrective maintenance is being performed on an ORU and the ORU cannot be removed for servicing, then the maintenance is also in-situ maintenance.

13.3.4 Levels of On-Orbit Maintenance

The ISS program uses three levels of maintenance: organizational, intermediate and depot. Each succeeding level requires a higher level of skill and more complex tools and diagnostic equipment. Details on each level are provided in Table 13-1.

Table 13-1. On-orbit maintenance levels

Level (Location)	Skills	Equipment required	Example
Organizational (performed on orbit)	Minimal maintenance skills	Standard hand tools, some diagnostic equipment	Visual inspections R&R of some ORUs Periodic cleaning/servicing of equipment Periodic checks of equipment performance External adjust/align ORUs
Intermediate - (performed IVA on orbit or on ground)	Higher level of skill(s) than organizational maintenance	More support/diagnostic equipment than organi-zational maintenance	Removal and replacement of major hardware components and assemblies Removal and replacement of ORU components, (i.e., circuit card assemblies).
Depot - (normally performed on the ground)		Specialized equipment not available on orbit Extensive collections of spare parts Complex diagnostic equipment	Complete overhauling/rebuilding of equipment (such as failed circuit cards). Complex calibrations of equipment

An ISS Multiplexer/Demultiplexer (MDM) can be used to illustrate the various levels of OOM. If a defective MDM is removed and replaced with a spare MDM, then Organizational maintenance is being performed. If a defective MDM is removed, carried to the MWA, the MDM opened up, a defective circuit card removed and replaced with a spare circuit card, then Intermediate level maintenance is being performed. If the defective circuit card is then carried to the ground where a failed integrated circuit chip on the card is replaced with a spare chip, then Depot level is being performed.

Note that when possible, some ORUs or failed components of ORUs are returned to the ground where depot level maintenance is performed on the ORUs/components. Once repaired, the ORU/component can be returned to orbit as a spare ORU/component.

13.4 On-Orbit Maintenance Strategy

The ISS On-Orbit Maintenance strategy involves four elements: tools, spare parts, procedures, and training. Each of these elements is discussed below.

13.4.1 NASA MWA/IVA Tools

Maintenance Work Area: The MWA is basically a portable work table (approximately 36 inches wide by 25 inches deep) which can be folded and stowed inside a storage drawer. (See Figure 13-1). In its folded configuration, the MWA measures approximately 15 inches by 26 inches by 9.25 inches. It clamps to the seat tracks on either side of a rack and can be rotated either up or down, as desired. The term “seat track” refers to a type of slotted mechanism often used on commercial airplanes to adjust the position of the seats. The MWA can be used to restrain ORUs while maintenance is being performed in a number of ways. First, seat tracks are built into the surface of the table which allows an ORU to be held to the MWA by clamps and other devices that interface with the seat tracks. In addition, slots in the surface allow the restraint of ORUs with bungee cords. The MWA is planned to be flown on Mission 6A.

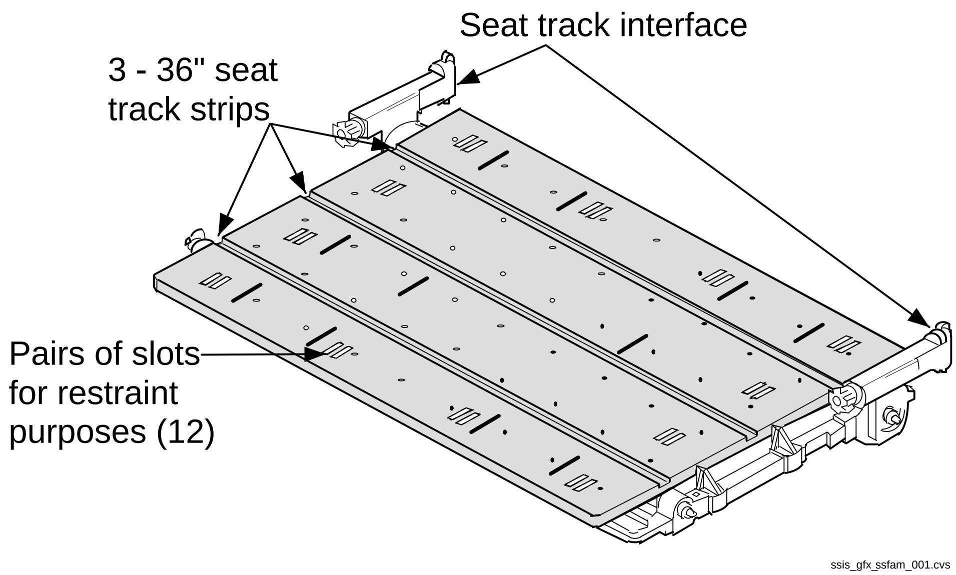

Figure 13-1. Maintenance work area (top view)

MWA Containment System: The MWA Containment System is a clear plastic enclosure designed to be used with the MWA to contain debris created by maintenance operations such as cutting, drilling, filling, or soldering. (See Figure 13-2). Rigidity is given to the enclosure by seven structural members, two arched members located at each end of the enclosure and five straight horizontal members which connect the two end pieces. When used, the enclosure and the structural members are removed from a storage drawer; the structural members are inserted into the plastic envelope and the entire structure is clamped to the surface of the MWA. When assembled, the containment system is approximately 34 inches wide by 24 inches deep by 26 inches high. Note that the MWA Containment System connects to the MWA in five locations: at each of the four corners and at a center baseplate in the “floor” of the containment enclosure. Other features of the MWA Containment System include: four gloveports, one in each end and two in one side; a 6-inch by 12-inch rigid, clear plastic viewing window; a 14-inch by 26-inch access flap for ORU access; a 6-inch by 12-inch filtered air intake; and two utility ports. The two utility ports are normally capped, but when necessary, either a vacuum hose or an electrical cable can be interfaced to either of the ports. Although the plastic envelope is considered to be a consumable item, the seven structural members are intended to be reused. Presently the MWA Containment System is planned to be flown on Mission 6A.

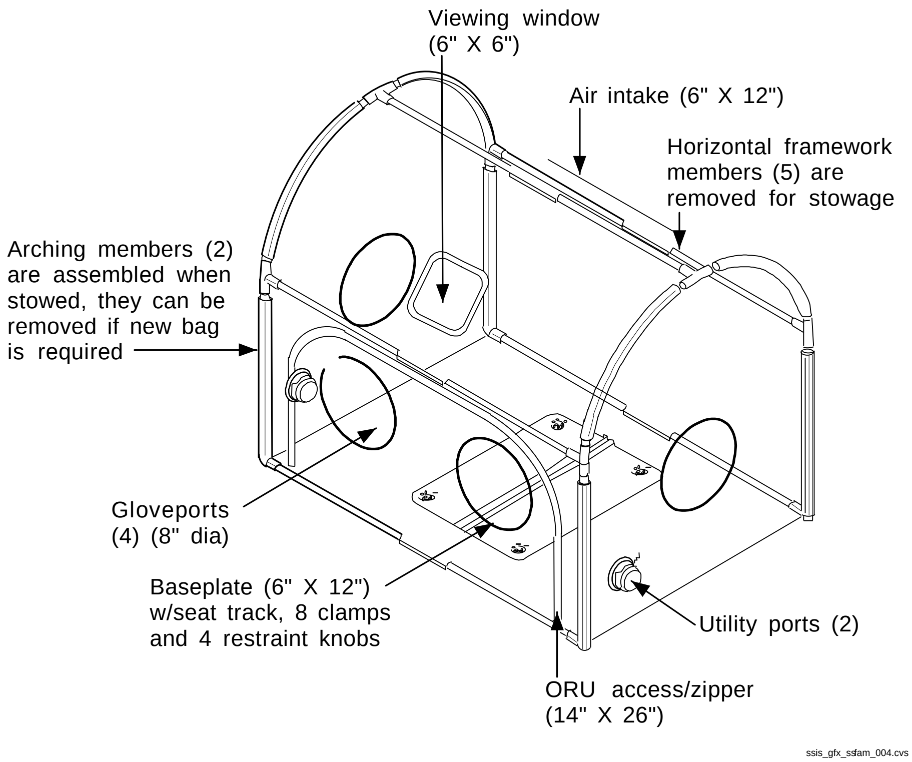

Figure 13-2. MWA containment system

On-Board Tools: Hand Tools - The ISS onboard tools are generally two types: hand tools and diagnostic tools. The hand tools can be further subdivided into EVA hand tools and IVA hand tools. The main differences between the two is EVA tools have special provisions for tethering and use by (EVA) gloved hands. (EVA tools are not discussed here). The IVA hand tools are basically the same type of common tools found in most automobile repair shops. The following is a list of typical types of IVA hand tools stowed in the ISS:

- Ratchets-powered/unpowered, torque, adapters, universal joints, breaker bars, extensions
- Sockets-regular/deep, Hex head
- Screw drivers - common-tip, Phillips head, jeweler’s
- Wrenches - open/box end, L-shaped, Hex head
- Pliers - various types
- Metal working tools - hacksaw, bone saw, chisels, punches, files
- Hammer - deadblow ball peen hammer

There is more than one set of IVA hand tools on the ISS. It is anticipated that the following sets will also be on the ISS:

- IP hand tools - Each IP will have a hand tool set for their respective module(s) (RSA, ESA, NASDA)
- Payload tools - Each payload is expected to provide any special tools needed to maintain their payload
- Special tools - For certain ORUs, special tools are required to remove and replace the ORU. In most cases, these special tools are packed with the replacement ORU
- Specialty tool kits such as
  - Electrical repair tools
  - Fiber optics repair kit
  - Fluid line repair kit
  - Hose and cable kit (similar to shuttle kit)
  - Tap and die set
  - Sewing kit

The NASA IVA hand tool set is unique in that it contains both English and metric sized tools. (Most of the IP tool sets contain only metric-sized tools). This tool set contains most of the tools which are in the shuttle In-Flight Maintenance (IFM) tool set in addition to a large number of new tools. The NASA hand tool set will be carried to orbit on Mission 2A. It is housed in a Nomex storage bag which is stowed in the overhead storage rack in Node 1. Within the storage bag, the tools are grouped into "kits" containing like tools (for instance, all the sockets in one kit, all the screw drivers in another kit, etc.). Each kit is contained within a Nomex pouch identified by a single letter of the English alphabet. The identifiers, along with a general description of the contents of the pouch is printed on the outside of each pouch.

On-Board Tools: Diagnostic Tools - The diagnostic tools are primarily used to perform fault isolation. Generally, the procedure is to remove a defective ORU, carry it to the MWA, open it up and use the diagnostic equipment to pinpoint which electrical component of the ORU has failed and in what manner. Once the defective ORU component is replaced, the diagnostic equipment is again used to determine if the repair was successful. After this, the ORU is closed and returned to its original location.

If the ORU cannot be removed from its installed location, the diagnostic tools can also be carried to the ORU and the maintenance performed in-situ. A description of available diagnostic tools follows.

Scopemeter: The Scopemeter, presented in Figure 13-3, is a commercially available combination of multimeter and oscilloscope manufactured by the Fluke™ company. It can be used to measure voltages, currents and resistance and to detect, digitize, store, and display waveforms with frequencies up to 100 Mhz. With its special probes, it can also measure temperature, and pressure. The Scopemeter has a liquid crystal display and is powered from a rechargeable power pack. An adapter is being developed which will allow the Scopemeter to receive its power from a standard ISS Utility Outlet Panel (UOP). A Scopemeter will be carried to orbit on both Mission 2R (on a Progress resupply vehicle) and Mission 6A.

Figure 13-3. Scopemeter

Pin kit: The ISS Pin Kit, presently scheduled to be flown on Mission 6A, is housed in a Nomex pouch and has some of the same components as the present Shuttle Pin Kit. The main difference between the two kits is all the shuttle-unique items are removed from the ISS Pin Kit and ISS components added.

The ISS Pin Kit contains

- Prefabricated jumper/test cables (in various wire gauges and lengths)
- Materials for manufacturing custom jumper cables (various gauges and lengths of wire and crimp-on connectors)
- Alligator clips, various type of test leads
- Assorted fuses

Logic Analyzer: The Logic Analyzer consists of a Portable Computer System (PCS), a Potable Computer Memory Card International Adapter (PCMCIA) card plugged into the PCS and LabVIEW software operating within the PCS. (See Figure 13-4). The PCMCIA card has numerous probes connected to it which allow the PCS to monitor several different points in a circuit, or several circuits, simultaneously. Although LabVIEW software has the capability to monitor any number of parameters, analog or binary, the Logic Analyzer application software is designed to monitor the logical state ("1" or "0", high or low, etc.) of particular points within a circuit or electronic component. The full capability of the Logic Analyzer will not be realized until Flight 6A.

Figure 13-4. Logic analyzer

Function/Sweep Generator - The Function/Sweep Generator, (presented in Figure 3-5) generates standard waveforms (sine wave, saw-tooth wave, square wave, etc.) to diagnose electronic circuits and perform fault isolation. Generally, the function/sweep generator is used to inject a known, reference signal (wave) into a circuit and the output of the circuit is monitored with the scopemeter or the logic analyzer (depending on whether the circuit is an analog or a digital circuit). The ISS function/sweep generator is an off-the-shelf function/sweep generator which has been adapted to operate from 120 V dc power and repackaged in a new cabinet. As Figure 13-6 illustrates, the top of the cabinet has compartments to house the scopemeter, scopemeter attachments, and the logic analyzer PCMCIA card. In this configuration, the function/sweep generator is sometimes referred to as the "Diagnostic Caddy."

Figure 13-5. Function/sweep generator

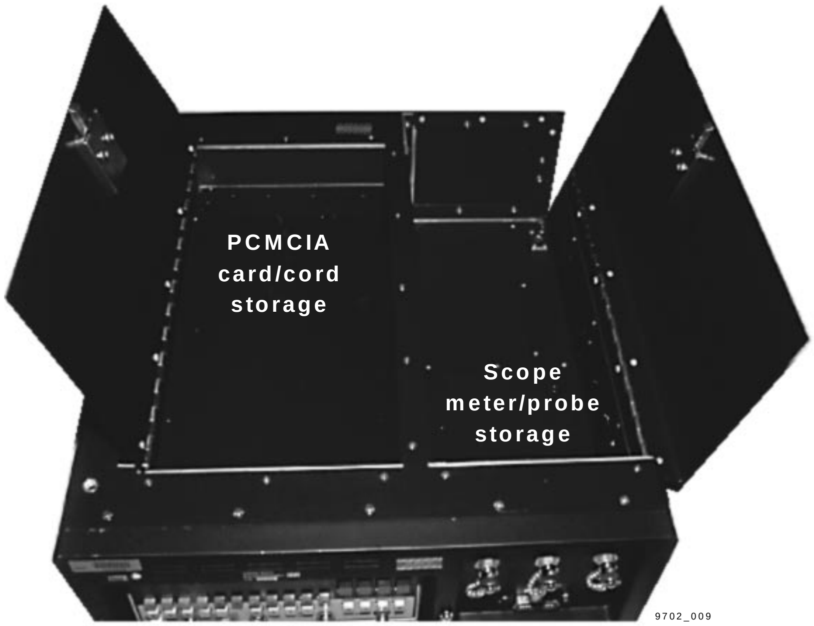

Figure 13-6. Diagnostic caddy

DC Power Supply: The DC Power Supply is designed to operate from a 120 V dc power supply. As shown in Figure 13-7, it plugs into a standard UOP and can be adjusted to provide voltages from 0-120 V dc and currents from 0-7 amperes. The dc power supply will be flown on Mission 6A.

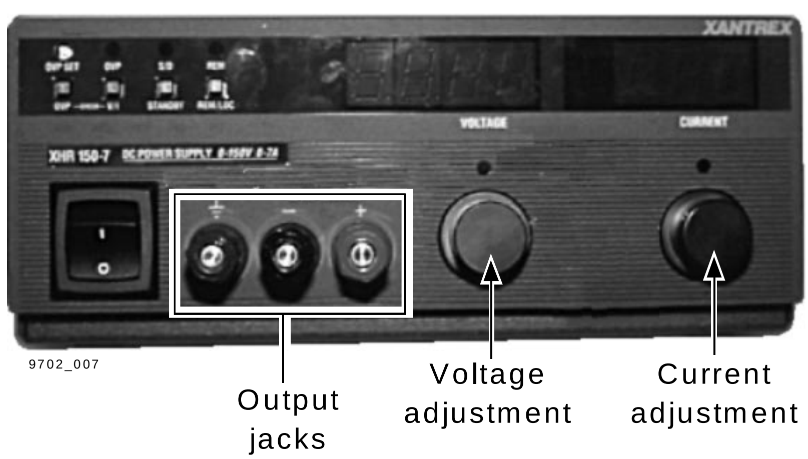

Figure 13-7. DC power supply

Power Strip: The Power Strip plugs into a standard ISS UOP and provides 4 UOP type sockets, each of which can be switched On and Off independently. It also has a removable fuse, as shown in Figure 13-8. Note that the four sockets on the power strip provide data connections as well as power. The power strip will be flown on Mission 6A.

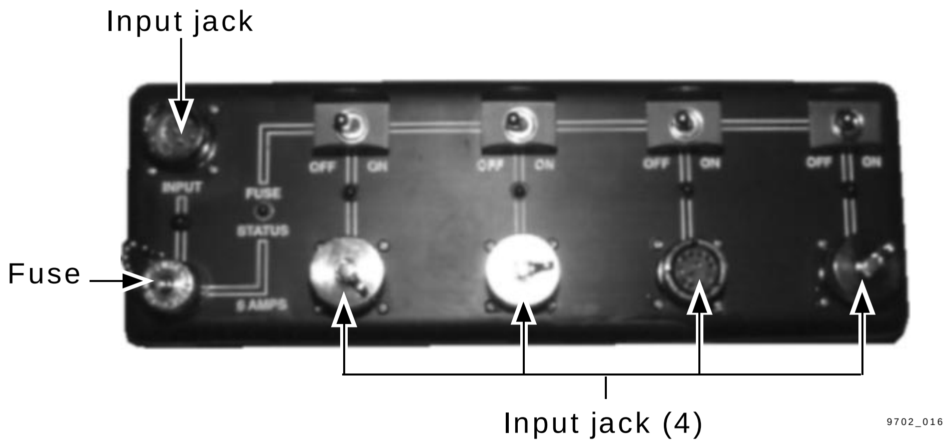

Figure 13-8. Power strip

13.4.2 Maintenance Logistics

Spares: As can be seen from the above description of ISS tools, the crew has a great deal of capability to diagnose and repair failed ISS ORUs and ORU components. Although some repairs can be performed by simply tightening a bolt or adjusting a seal, most ISS repairs require a spare ORU or spare parts for an ORU.

Maintenance logistics spare parts include: procurement; storage; inventory; transportation (both to the storage area and to the worksite); and tracking of ORU failure modes and lifetime.

For the ISS program, a quantity of selected spares were purchased even before any component of the ISS was launched. Due to financial considerations, it was impossible to provide spares for every ORU on the ISS. Therefore, the following factors were considered when determining which spares to purchase:

- The criticality of the ORU to crew safety, vehicle integrity, or mission success
- Mean Time Between Failures (MTBF) for the ORU in question (based on tests of a quantity of the ORU;, the average length of time the ORU operates without failing.)
- The quantity of that particular type of ORU on the ISS
- The availability of operational “work-arounds” if the ORU fails
- The availability of launch vehicle volume and weight allowance to carry the ORU to orbit

A spare part purchased, based on the above criteria, and scheduled to fly on a future mission is referred to as a preplanned spare.

A spare, already onboard the ISS and available for future use, is referred to as a prepositioned spare. (The present plan is to have the equivalent of three racks of spares onboard the ISS by Mission 8A).

If an ORU fails on the ISS and a spare ORU cannot be acquired in a timely manner, the required maintenance is postponed and the spare is referred to as a backlogged spare.

If an ORU performing a critical function fails, and another ORU of its type is available on orbit, and is performing a function deemed less critical than the first, the second ORU may be "borrowed" to perform the more critical function. The spare in this case is referred to as a borrowed (or "cannibalized") spare. When a spare becomes available, it is placed in the position of the second ORU; the borrowed ORU, performing the more critical function, is not replaced.

Ground Support of Maintenance Logistics: Although the Operations Support Officer (OSO) is the primary Mission Control Center-Houston (MCC-H) discipline concerned with OOM, almost every discipline in the MCC-H is involved in some aspect of OOM. The OSO performs the following activities on the ground in support of maintenance logistics:

a. Tracking of ORU failures

b. Determination of the availability of spare ORUs

c. Initiation of spare ORU procurement

d. Generation of maintenance procedures

e. Updating of maintenance databases

The primary tool the OSO uses to perform items b, d, and e is the Consolidated Maintenance Inventory and Logistics Planning (CMILP) system. CMILP is a software application contained within the Integrated Planning System (IPS) in the MCC-H. IPS is a ground-based system and is used to develop maintenance procedures and control parts inventory and has the capability to access the Logistics Support Analysis Records (LSAR) maintenance database.

On-Orbit Maintenance Prioritization: At any time during the lifetime of the ISS, there may be numerous ORUs which have failed. Some of these failures may be serious, while others may have less impact. With the limited resources available (particularly crew time) a process had to be developed which allowed prioritizing of these repairs to make the best use of the available resources. This process is projected to proceed as follows:

- The system operator in the MCC-H detects, or is informed of, a system anomaly and aids in performing Fault Detection Isolation and Recovery (FDIR) to the ORU level.
- The system operator declares the ORU as either
  - Failed
  - Operating in a degraded mode
- The ORU is placed on the Designated Item (DMI) list
- The DMI list is prioritized, based on
  - Station and Crew Survival

- System Criticality
- Availability of Spare ORUs
- Crew time availability

13.4.3 Maintenance Procedures

Elements of a Procedure: A maintenance procedure is a sequenced set of steps that describe how to remove, replace, repair, inspect, calibrate, or adjust an ORU or ORU components. Most ISS core maintenance procedures contain the following eight basic elements:

- List of required tools/spare parts
- Safing steps - Removing electrical power, or pressure, from the maintenance site
- Access steps - Steps taken to get access to a failed ORU. This may require removing panels or rotating racks
- Remove steps - Removing the old part
- Replace steps - Installing the new part
- Check-out steps - Steps taken to ensure the new part works in its new location. This may require turning on power to the new part
- Close-out steps- Reinstalls any access panels which were removed for access
- Postmaintenance - Stowing the tools, and defective ORU and maintenance record keeping

Procedures Generation: Failures occur for which there are no predefined maintenance procedures; when this occurs, the necessary procedures are written “real time,” as required.

Location of Maintenance Procedures: Some basic group of predefined procedures are stored onboard on a CD ROM or as a part of the System Operation Data File (SODF) and accessed by a PCS. Additional procedures are uplinked from the ground as they are required. As a minimum, the following types of maintenance procedures are stored onboard:

- Routine/Preventative Maintenance Procedures - These are performed on a relatively frequent basis
- Emergency Procedures - The crew needs immediate access to these procedures, when required

13.4.4 Maintenance Training

As we have mentioned before, crew training in maintenance techniques is an element that enhances our ability to make successful repairs on the ISS. All crewmembers receive basic and advanced training in OOM techniques. Selected members of the crew receive additional, increment-specific maintenance training. Since time does not permit training crewmembers on all possible OOM procedures, the emphasis is on teaching basic maintenance skills. However, some specific routine and critical maintenance procedures are covered in training.

Examples of basic maintenance skills

- Tool Usage
  - Hand tools
  - Soldering
  - Gluing
  - Cutting/swaging
- Hardware Access
  - Rack tilt-down
  - Close-out panel removal
- Procedure Execution
  - Only the most critical and the most common procedures are taught on the ground

IPs and payload providers are responsible for providing crew training for their specific modules/equipment. This training takes place at their respective facilities (based on mockup fidelity). NASA and RSA may coordinate the teaching of basic maintenance skills. (i.e., NASA might teach gluing skills; RSA might teach soldering skills, etc.).

13.5 Summary

- ISS OOM has a completely different philosophy than IP. Permanent repairs must be made on orbit.
- IPs are responsible for maintenance activity on their respective components of Station hardware.
- The four types of OOM are: preventive, corrective, in-situ, and contingency
- The three levels of OOM are: organizational, intermediate, and depot
- Our philosophy for ISS OOM is to maintain, repair, and replace ISS ORUs with the goal of returning the affected systems to their original configuration. This goal is obtained by using
  - Tools
    - Hand tools
    - Diagnostic tools
  - Logistics

    - A supply of spare ORUs
    - Planning/prioritization
  - Procedures
    - Extensive collection of prepared procedures
    - Stored on PCS or uplinked, as needed
  - Training - All crewmembers well trained in basic/advanced maintenance skills
    - Emphasis on maintenance skills, not procedures
    - Selected maintenance procedures

The following is a typical scenario followed in the event of an ORU failure, indicating the responsibilities of the various disciplines involved:

- Crewmembers
  - Report defective ORU(s)
  - Assist flight controllers in troubleshooting “questionable” ORU
- Systems Operator/Flight Controller
  - Troubleshoots his (or her) system(s)
  - Determines which ORU has failed
  - Puts affected system/ORU in safe configuration
- Operations Support Officer (OSO)
  - Prioritizes maintenance tasks
  - Writes OOM procedures
  - Coordination of maintenance procedures among IVA, EVA, and EVR disciplines
  - Determines if appropriate spare ORU is onboard
  - Submits list of failed ORUs and suggested manifest changes to Maintenance and Repair IPT
- Maintenance and Resupply IPT
  - Procures spare ORUs (in response to OSO’s request)
  - Manifests spare ORUs
- Crewmembers
  - Remove and replace failed/degraded ORU

Questions

Identify the type and location of OOM being performed in the following tasks. Choose the best fit, since activities may overlap.

On-Orbit Maintenance (OOM)	Tasks
Types a. Preventative b. Corrective c. In-Situ d. Contingency **Methods** I. IVA II. EVA III. EVR	1. ____ ____ Internal water loop repair 2. ____ ____ Module pressure vessel leak repair 3. ____ ____ Scrub module internal walls 4. ____ ____ Remove and replace malfunctioning MDM 5. ____ ____ Module filter cleaning